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Author(s): Pemberton, Steven James
Sandoval, Thomas D.

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CORRTEX Analysis Techniques

Steven Pemberton and Tom Sandoval

J-NV, Nevada Operations

An introduction is given to CORRTEX system design and analysis concerns, and a new, algorithm for the analysis of CORRTEX data is presented. The new algorithm is based on techniques from wavelets theory, and improves pulse discrimination in the presence of baseline curvature and non-ideal experimental circumstances. Some results are presented to illustrate the use and robustness of the pseudo-wavelets approach.

1 Introduction

Continuous Reflectometry for Radius versus Time Experiments, or CORRTEX, is a diagnostic that was developed during nuclear testing to measure the distance at which rock walls were disrupted by an explosive device as a function of the time at which disruption occurred. Distances recorded are dynamic measurements of cable length as the shockwaves from an explosive event crush the experiment cables, reducing their usable length.

Applications of the CORRTEX diagnostic have been expanded in recent times to include instrumentation of the explosive device itself, to record phenomena such as the speed of the detonation wave in the explosive charge and the crushing or disassembly of material in the charge housing. The diagnostic has likewise been used to monitor explosive performance in rock blasting and oil well hole-clearing activities.

2 System Design

A CORRTEX system is a high repetition-rate Time-Domain Reflectometer (TDR). Such a system comprises a pulse generator, a signal cable, a return signal coupler, and a recorder for TDR data. Optionally, the system may also include a signal amplifier, filters to eliminate noise in the outgoing and returning signals, and/or signal analysis electronics to convert the data from raw voltage signals into measurements of cable delay. LANL systems typically operate with frequencies between 100 kHz and several MHz.

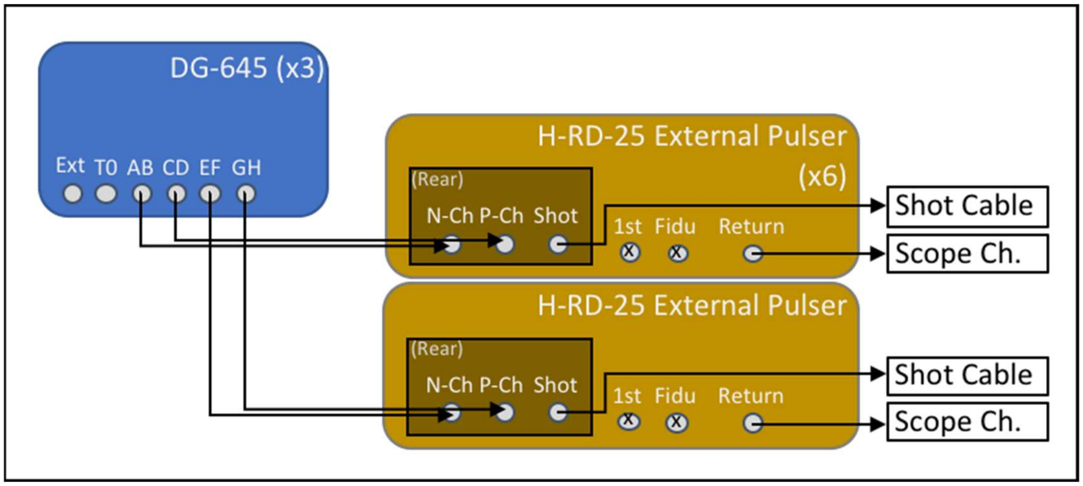

Figure 1. CORRTEX channel wiring; two channels are represented within a system of six channels total.

Figure 1 illustrates the components in an example LANL CORRTEX system. This is an updated and simplified system compared with the systems fielded during nuclear test days. For this system, DG-645 units from Standard Research Systems were used to generate square pulses at a frequency of 100 kHz, and EG&G H-RD-25 units then amplified the pulses for transmission down the CORRTEX data cables to the experiment, and filtered return pulses for recording. Each H-RD-25 unit includes a directional coupler that receives amplified input pulses from the electronics and relays them to the data cable, then receives the reflected signal – after round-trip transmission on the cable – and relays it through signal filters to the recording channel on a digitizing oscilloscope.

System design concerns include:

1. Pulse repetition rate;
2. Output pulse shape;
3. Output power level;
4. Choice of signal cable; and
5. Choice of analysis algorithm.

Each concern is discussed briefly below.

2.1 Operating Frequency

The pulse repetition rate, or operating frequency, of a CORRTEX system equals the rate at which measurements of the cable length are collected. A frequency of 100 kHz therefore yields a measurement of cable length every 10 microseconds, and gaps in time several microseconds in duration between individual pulses in the voltage data. These gaps simplify analysis of the data by easing discrimination between pulses. However, many explosive experiments reach completion after only a few measurements can been made at this rate.

The choice of pulse rate therefore involves a balance between measurement frequency and the ease of analysis.

It should be noted that long cables don't preclude the use of high repetition rates. LANL experimenters have found that pulses can 'leapfrog' without causing undue difficulty to the analysis. In other words, the delay between output and return pulses can be longer than several times the pulse period if the duration of an individual pulse is short enough to enable discrimination, and if pulse timing is chosen to ensure return pulses occur between output pulses. Illustration of this technique is given later in this report.

2.2 Pulse Shape

The primary factors in the output pulse shape are the duration and the peak voltage. During analysis, pulse identification is made easier by employing high voltage pulses of short duration. However, an output pulse with high peak voltage and sharp contours is more prone to dispersion when transmitted long distances, resulting in an altered and extended shape in the corresponding return pulse. Alternatively, long duration pulses can lead to overlap between return pulses and ensuing output pulses. In addition, signals with high voltage and high frequency could constitute significant RF energy, and may present safety hazards to personnel and experiment hardware. The choice of pulse shape can therefore be important.

Figure 2 shows an example pulse configuration from a nitromethane rate stick conducted at LANL in 2017. Pulse frequency in the data shown was 3.5 MHz, and the nominal cable length was 129 meters. In the figure, the square pulse on the left is an output pulse, and the inverted triangle on the right is a corresponding return pulse. The effect of signal dispersion is clear when the output pulse shape is compared with that of the return pulse. The output pulse duration was also extended from roughly 13 nanoseconds to about 70.

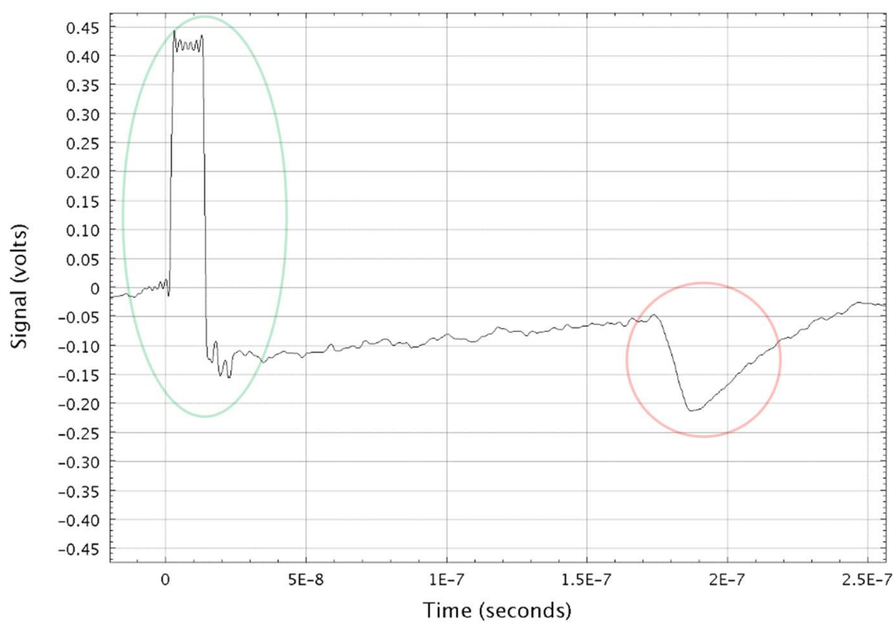

Figure 2. Example pulse from a rate stick experiment. Output pulse is on the left, and a return pulse is on the right; signal dispersion is clear from a comparison of the two pulse shapes.

Figure 3 shows an example pulse configuration from the Dry Alluvium Geology (DAG) experiments at the Nevada National Security Site (NNSS). The altered shape of the pulses results from filters within the pulse amplifier; the raw output pulse was relatively square.

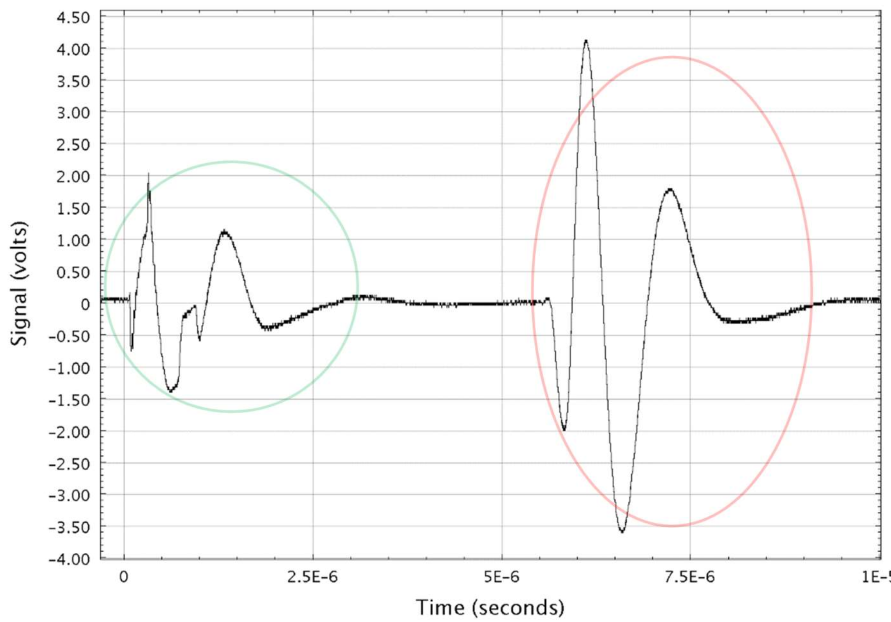

Figure 3. Example pulse from a DAG experiment. Pulse shapes are highly modified by electronic filters; the raw output pulse had a duration of 200 ns, but the filtered pulses were of order 4 microseconds in total length.

2.3 Output Power

The voltage level in the output signal must be sufficient to yield a return signal with voltages high enough for detection and discrimination from background noise. Higher voltages result in data that is easier to analyze, but can also require the addition of amplification hardware in the system.

Data for the DAG series were collected using a system with 90-volt output levels, and the resultant return signal level can be viewed in Figure 3, above. These data were easy to analyze and resulted in easy discrimination between output and return pulse shapes. By contrast, the pulse configuration from the Integrated System Test (IST) experiment is shown in Figure 4. The output pulse at the left is easy to identify, but the return pulse appears as a small bump to the right, and is virtually identical to the voltage pulse between the two, which is believed to have come from a cable connection in the field but upstream of the experiment. Analysis of IST data was difficult due to the low signal levels returned, and due to the large curvature in the voltage baseline following each pulse. An increase in the output signal power would have increased the return pulse voltage levels and made analysis far easier, if it had been possible without modifying the output pulse. Similarly, a cleaner output pulse shape, with a return to a flat baseline, would have made pulse discrimination much simpler. Analysis of the IST data is discussed more in section 4.3, below.

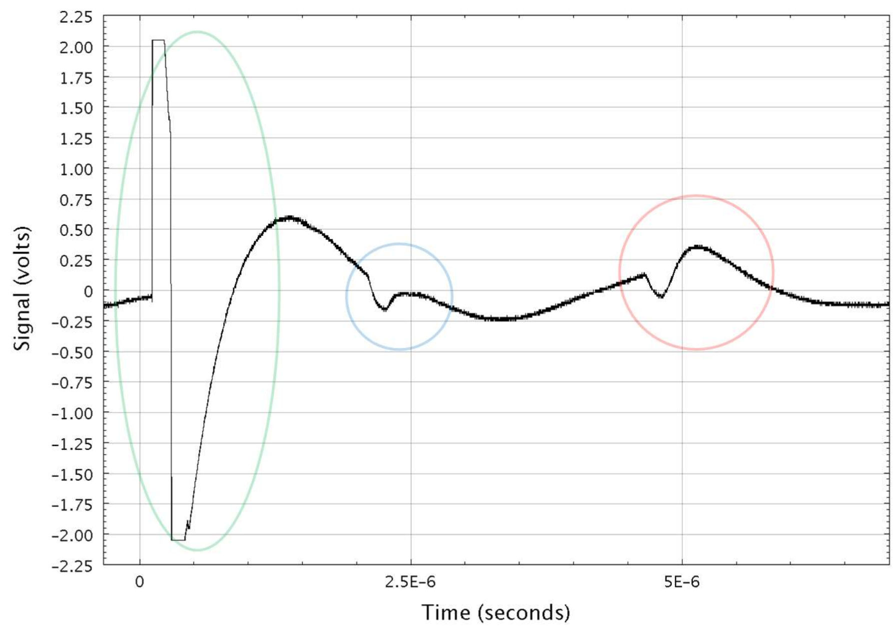

Figure 4. Example pulse from the IST experiment. The saturated wave at the left (in green) is the output pulse, and the small mound at the right (in red) is the return pulse. The mound at 2.5 microseconds (in blue) is believed to have come from a cable connection upstream of the experiment location.

2.4 Cable Choice

Selection of the best signal cable for an experiment can also be important to the success of experiment fielding. This may be less important on an experiment like DAG, where cables were installed between two sheets of metal adjacent the explosive, and crush of the dielectric in the cables was inevitable. However, in some experiments destruction of the cable is less certain. In some nuclear tests, for instance, CORRTEX cables were installed in a soil bed many meters from the nuclear experiment. Because the experimentalists were uncertain how well those cables would respond to the propagating shock front, the choice was made to use an air-dielectric cable which had virtually no strength.

2.5 Analysis Concerns

Algorithms for CORRTEX data analysis will be covered in the next section. However, issues of concern for all analysis approaches include:

1. EMI from the experiment;
2. Reflection at the end of the data cable (the short circuit);
3. Initial cable length 'jump';
4. Crush promptness; and the
5. Recording trigger.

Some discussion of these is included below.

2.5.1 Electromagnetic Interference (EMI)

The capacitive discharge unit (CDU) and detonators for the experiment can emit significant electronic noise that can interfere with signal analysis and pulse discrimination, as can other electronics in the testing environment. Analysis techniques should account for this noise in some way.

2.5.2 Cable Short-Circuit

In general, CORRTEX cables are short-circuited at the end prior to installation in the field. This short circuit results in clean return signals, and causes inversion of the output signal on return to the CORRTEX system. The concern during analysis relates to the phenomena that shorten the signal cable during the experiment. If the cable is crushed cleanly, then destruction of the cable causes a new short circuit at the truncated length, and the only change in the signal level results from the decrease in attenuation (and dispersion) due to the shortening of the cable. However, if the crush of the cable is incomplete then an electrical short circuit may not occur, and the cable may be left in an 'open' state. An open circuit would result in signal reflection without inversion, and a partial closure could weaken or absorb the CORRTEX signal. Any analysis technique therefore needs to account for such variations by 1) recognizing return pulses that are 'upside-down' compared to the expectation, 2) discarding pulses that are not found during discrimination, or some combination of (1) and (2).

2.5.3 Initial Jump

CORRTEX cables are often installed in such a way that some amount of cable is instantly truncated at the start of the explosive experiment. This can provide a useful fiducial at the start of data when the cable length 'jumps' from its initial length to something significantly shorter. For example, prior to execution of each DAG experiment, CORRTEX data cables extended 12 inches to several feet beyond the length needed for data collection. This led to clear demarcations in the data, the size of which indicated the location at which cable destruction began.

2.5.4 Crush Promptness

CORRTEX systems provide a measurement of the round-trip delay between the pulse generator and the short circuit at the end of the data cable. Depending on the nature of the experiment, that short circuit may be very close to the current location of the shock wave that is the subject of measurement, or it might be some distance beyond it. This is due to the delay between the time of shockwave arrival at the cable's outer surface and the time when the cable is sufficiently crushed to cause a short-circuit (or open circuit) that reflects the CORRTEX signal.

2.5.5 Recording Trigger

In practice, digitizers used to collect CORRTEX data are activated before the start of the experiment. This delay provides time during which useful baseline data can be collected prior to any change in the cable's length. This baseline data can be used during analysis to determine as-fielded signal delays between the output and return pulses, and these delays can be compared with the as-built cable length to give a quantity for comparison with the shortened cable length that later results from the experiment. Because signal transmission speeds are a function of environmental conditions as well as cable type, this can be a valuable calibration to perform at the time at which the experiment is conducted.

3 Analysis Techniques

3.1 Early Analysis

When CORRTEX was first developed as a diagnostic, it was impractical to record the electrical signals received from the system for analysis at a later time. Because of this, signals were actively analyzed as data were received, and analysis techniques were limited to those made possible by the electronics available at the time. Data recording was limited in early systems to a few thousand numbers, and the numbers saved were measurements of the reduced round-trip transmission time in a CORRTEX cable.

The primary method used to analyze signals from early CORRTEX systems was based on voltage thresholds, and involved recording the time(s) at which a cable's return signal level rose from low to high voltage and passed a pre-set voltage level. Figure 5 and Figure 6 show example pulses from CORRTEX data as marked using a threshold-crossing algorithm.

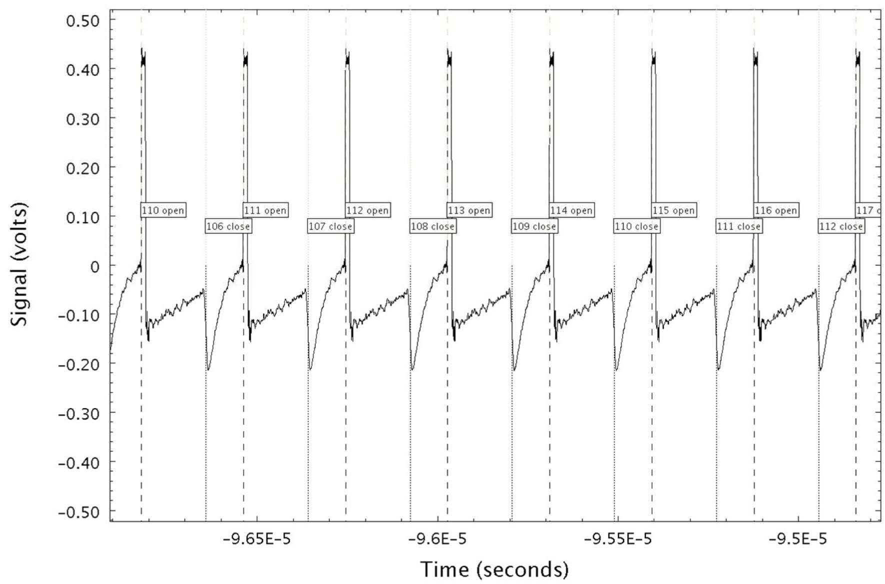

Figure 5. Rate stick CORRTEX data with pulses marked by threshold analysis; note that pulse generation was set up with a four-pulse 'leapfrog', so pulse 110 opens at left, and then closes after four additional output pulses are registered. Pulse identities appear immediately to the right of their respective marks.

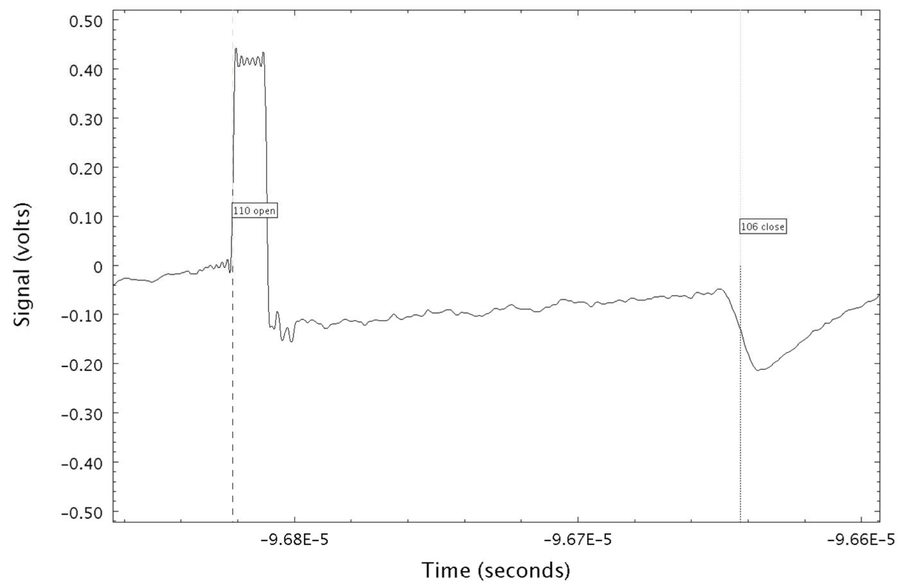

Figure 6. Rate stick CORRTEX data as in Figure 5, but focusing on a single output and a single return pulse; effect of threshold choice can be clearly seen with the right-hand pulse.

Various techniques were used to improve the results from threshold-based signal analysis. These included time discriminators, to prevent the detection of a new pulse too soon after another pulse, and voltage discriminators, which were designed to detect both negative-going and positive-going threshold crossings to prevent data loss that would otherwise occur when the electrical connection wasn't properly short-circuited at the end of the cable.

Some techniques were also built into CORRTEX pulse discriminators to detect and eliminate false triggers, which were expected to occur due to noise in the environment, or missed triggers, which could result from faulty signal lines in challenging fielding situations. In the case of false trigger detection, the onboard analysis system was programmed with instructions to examine the results immediately following data collection; if the cable length did not change substantially during collection, then the system would rearm. In order to detect missed triggers, the system would continuously monitor the cable round-trip time, and if that time diminished in five or more consecutive measurements then a trigger was assumed and data were collected. The advantage of this approach is that CORRTEX systems could then be used to trigger other diagnostics and avoid potential data loss and the substantial loss of investment represented by such a data loss.

Because CORRTEX data are not actively analyzed by modern systems, there is no longer built-in compensation in the systems for lost or false triggers. To implement robust trigger analysis, investments would be needed to design new active analysis circuitry – or to modernize legacy circuitry.

3.1.1 Sources of Error

Prior to an experiment, transmission speeds in the data cables were carefully measured as a function of cable length by recording the round-trip delay imposed by a cable, shortening the cable by a known distance, and then remeasuring the delay. By repeating this process several times, the linearity of the transmission delay could be confirmed, and by recording the shape of the return pulses at each length, information could also be gathered about the attenuation and dispersion of the pulse shape as a function of the cable length.

Sources of error from use of a threshold-based algorithm include:

1. Any shift or slope in the baseline voltage level between pulses can lead to systematic changes in the delay between pulse arrival and threshold detection; these changes will likely worsen as the cable is shortened.
2. Any difference in the path delay between the output pulse signal path and the return pulse signal path could lead to a systematic error in the measurement of absolute cable length.
3. Electrical noise can affect the signal enough to cause a threshold change in voltage level and false detection of a pulse.
4. Decrease in signal attenuation and dispersion can result in shorter delays between signal arrival and threshold detection, leading to a systematic decrease in detected cable length that worsens as the cable is shortened.

Aside from electrical noise, systematic sources of error can be minimized through careful design of the pulse generation and filtering, and through measurement of factors that affect attenuation and dispersion in the cable.

3.2 Pseudo-Wavelets Analysis

One recent approach to the analysis of CORRTEX data utilized a technique from wavelet theory. In general, a wavelet transformation involves the comparison of a brief oscillation pattern – for instance a single period of a sinusoid – to a data signal in order to identify occurrences of that pattern within the signal data. The full theory behind this technique and its applications will be left to textbooks on the subject; however, the technique was simplified and reduced for rapid application to CORRTEX signals for pulse identification, and the simplified approach is included here. This approach was made possible when full data records could be stored from an experiment for later analysis – though advances in modern electronics may make it possible to build an active discriminator that uses this technique.

The patterns chosen for identification within CORRTEX data – the "mother wavelets", to use the term from wavelet theory – are those of the output and return pulses within the signal's baseline region. A nominal output pulse, for example, can be either an average of all the output pulses within the baseline data, or a single instance of such a pulse. Similarly, a nominal return pulse can be extracted from the baseline data by averaging all baseline return pulses or by choosing an example from among those pulses. A nominal pulse can be created by averaging data values as:

$$pulse_i = \frac{1}{n} \cdot \sum_{j=0}^{n} data_{i+m_0+j\cdot m} \tag{1}$$

where the index i is used to indicate values within the pulse and the data, m_0 indicates the indicial offset (number of timesteps) to the start time of the first pulse, m the offset between pulses, and n the total number of pulses averaged.

A search of the full data signal is then conducted using the nominal pulse to locate instances of that nominal. This is done by multiplying the voltage values in the nominal pulse by values in the data to form a new record with the same granularity as the original signal, which can be called the integral:

$$integral_i = \frac{1}{C}\sum_{j=0}^{p} data_{i+j} \cdot pulse_j \quad (2)$$

where p indicates the length of the nominal pulse, and the constant C is a normalization constant:

$$C = \sum_{j=0}^{p} pulse_j \cdot pulse_j \quad (3)$$

As constructed, then, each point i in the integral reflects the sum of p products of data and pulse values beginning at i. This integral generally has a maximum value when the shape of the data values matches the pulse shape, but a value closer to zero at all other locations. In cases when a data pulse is inverted relative to the nominal, the integral has a maximum *negative* value. An inverted pulse can therefore be easily identified.

Figure 7 shows an example analysis of output pulses using the rate stick data displayed in earlier figures. When locating output pulses, analysis can be accelerated by only computing the integral curve near the expected pulse locations (i.e. only in allowed locations). However, for completeness the disallowed regions have not been suppressed in the figure, as the allowable duration for output pulses is very short.

Figure 8 shows the respective return pulse analysis, in which disallowed regions of the integral have been suppressed.

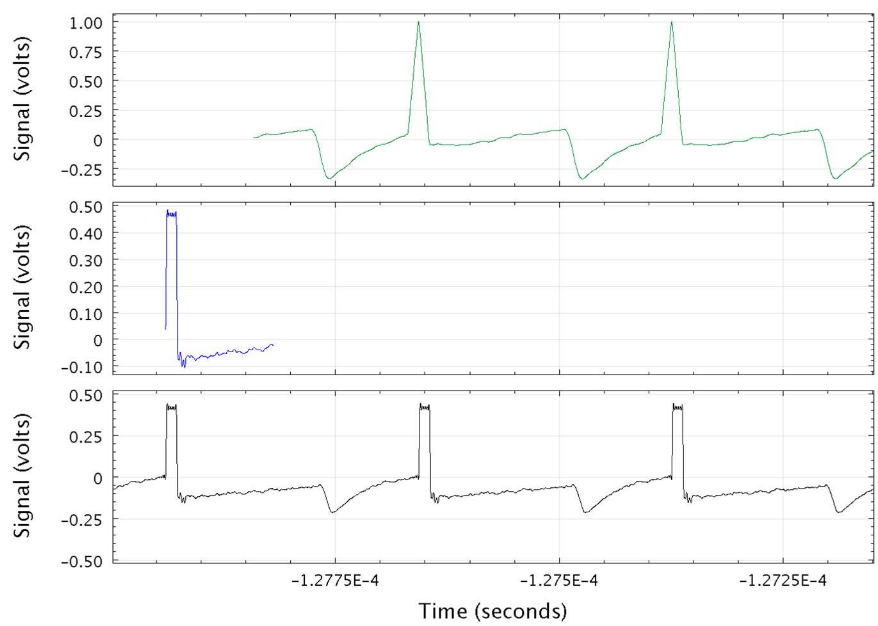

Figure 7. Rate stick analysis for output pulses. The original data is given in black at the bottom, with the nominal output pulse in blue above that, and the integral curve in green can be seen to reach its peak at each output location.

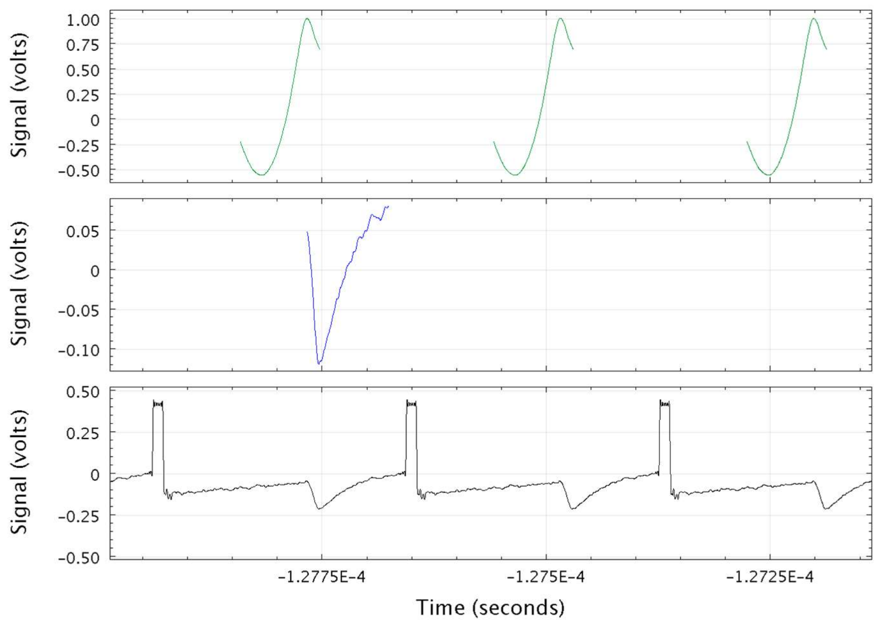

Figure 8. Rate stick analysis for return pulses. As with the analysis in Figure 7, the green integral curve at the top can be seen to reach a maximum when the data signal matches that of the nominal return pulse. The integral has been suppressed in regions where return-pulse detection is disallowed.

Once the nominal output and return pulses have been defined and integral curves have been computed for a CORRTEX signal, it remains to choose pulse locations by examining the integral curves. This is accomplished by marching through each integral and selecting the maximum positive (or maximum negative, in the case of an inverted pulse) at each prospective pulse location. The pulse location is then carefully resolved by fitting a quadratic to the handful of points nearest the maximum and calculating the peak of that fit. By using the location of this peak instead of the location of the maximum value itself, the influence of signal noise can be minimized during the analysis. This also allows for discrimination of pulse locations with uncertainties lower than the sampling interval in the data.

Following identification of the pulse locations within the output and return pulse integrals, output pulse locations are paired with return pulse locations into round-trip cycles. The time difference within each pair is recorded as the round-trip time delay for the cycle, and the mid-point between the output and return pulse locations is recorded as the time of signal reflection.

In practice, the cycle delays recorded during the baseline region are used to confirm the operational frequency and to measure the round-trip delay prior to the start of the experiment. Delays recorded after the experiment begins can then be compared to give an estimate of the change in cable length as the experiment progresses.

A comparison of the threshold-based and pseudo-wavelets techniques is shown in Figure 9 for the rate stick data. Because the data were very good from this experiment, the two algorithms compare favorably.

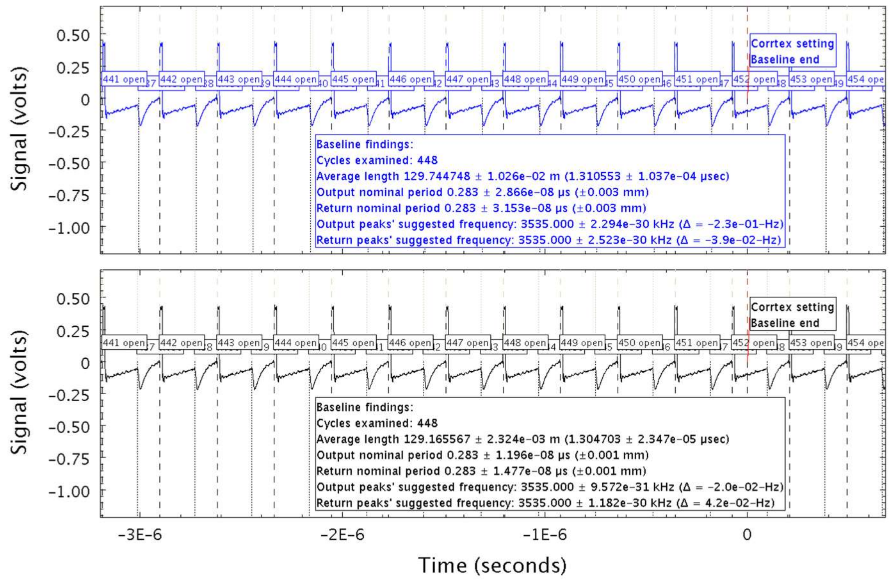

Figure 9. Comparison of threshold (in blue) and pseudo-wavelets (in black) techniques for the baseline region of the rate stick data presented above. Results are similar, with a difference in the nominal cable delay of about 6 nanoseconds that results in the threshold algorithm due to the difference in the initial slopes of the output and return pulses.

Sources of error from use of the pseudo-wavelets technique are reduced compared to a thresholds-based technique. It is still necessary to understand the time difference between the output and return pulse transmission path in order to accurately measure the absolute cable length. This path difference will also be manifest as a small (few nanosecond) systematic error in the time of reflection recorded in the analysis. However, the pseudo-wavelets technique is very robust against baseline shifts and baseline curvature in the signal voltage, as will be demonstrated below in discussion of the IST data analysis. The technique is also very robust against electrical noise in the signal.

The pseudo-wavelets technique described can still be adversely affected by a significant change in the signal attenuation as the cable shortens, or by partial absorption of pulses by an incomplete short-circuit at the cable end. If these effects are found to be important, the technique could be expanded into a more complete wavelets technique in the future by computing additional integral curves using slightly amplified (for lower attenuation) and slightly reduced (for partial absorption) mother wavelets. The maximum among the integrals would then be compared, and the largest of those values would indicate the best match – and detection time – for a nominal pulse.

4 Comparison of Analysis Techniques

4.1 Rate Stick Data

The data shown in the previous section was from a rate stick experiment conducted with pure (non-sensitized) nitromethane in Los Alamos in 2017. CORRTEX cables for this test were fastened along the outside surface of a cylindrical explosive charge, which was initiated at one end. Signals in the data were relatively clean, and a comparison of the baseline region using the threshold and pseudo-wavelets algorithms (as in Figure 9) showed favorable results. The same could be said of the data in the active region following initiation of the explosive, which is shown in Figure 10. The difference between the two sets of results can be seen to start around 6 nanoseconds and persist at a similar level throughout the experiment.

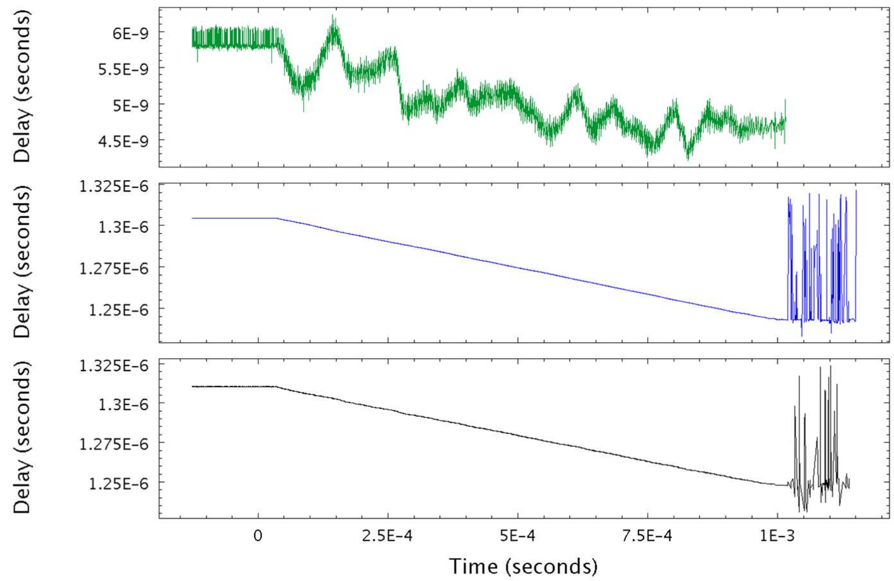

Figure 10. Rate stick results following detonation. Threshold analysis results are in black, and pseudo-wavelets results in blue. The green curve shows the difference between the two; this curve is truncated at the point where cables are rendered unusable.

4.2 DAG Canister Data

The Dry Alluvium Geology (DAG series of experiments were conducted at the Nevada National Security Site (NNSS) in 2018 and 2019. The series included several experiments that each employed a center-initiated charge of pure nitromethane. CORRTEX was used to measure the detonation wave speeds that resulted in each test and to confirm the symmetry and uniformity of detonation performance. Of particular interest for this paper was the DAG-1 and DAG-2 experiments: DAG-1 because it was similar in geometry to the IST test, discussed below, and DAG-2 because it included a more substantial amount of nitromethane and therefore allowed a very good measurement of the detonation development.

4.2.1 Experiment Design

CORRTEX cables were installed along the outer surface of the DAG canister, and inside tubes that extended within the DAG canister near the central axis of the cylinder. Photographs of the DAG-1 and DAG-2 experiment canisters are shown in Figure 11. The DAG-1 experiment employed the TNT equivalent of one metric ton of nitromethane. The DAG-2 canister was similar in construction but employed 50 metric tons (TNT equivalent) of nitromethane.

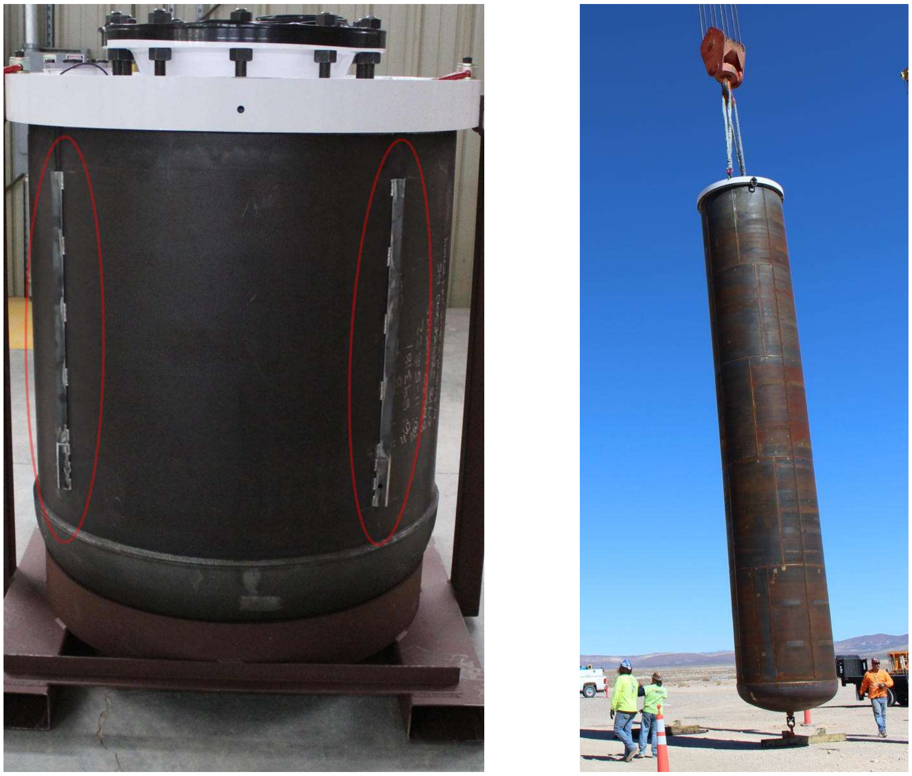

Figure 11. Photographs of the DAG-1 (left) and DAG-2 (right) experiment vessels; CORRTEX cables were inserted along the walls where circled (x4 total in each experiment) and near the central axis of the canister (x2 in each).

4.2.2 Baseline Analysis

As with the nitromethane rate stick data discussed above, data for the DAG experiments was relatively noise-free and provided good examples of CORRTEX data for comparison. Data were analyzed using both the threshold algorithm and pseudo-wavelets algorithm, and baseline results are included as Figure 12.

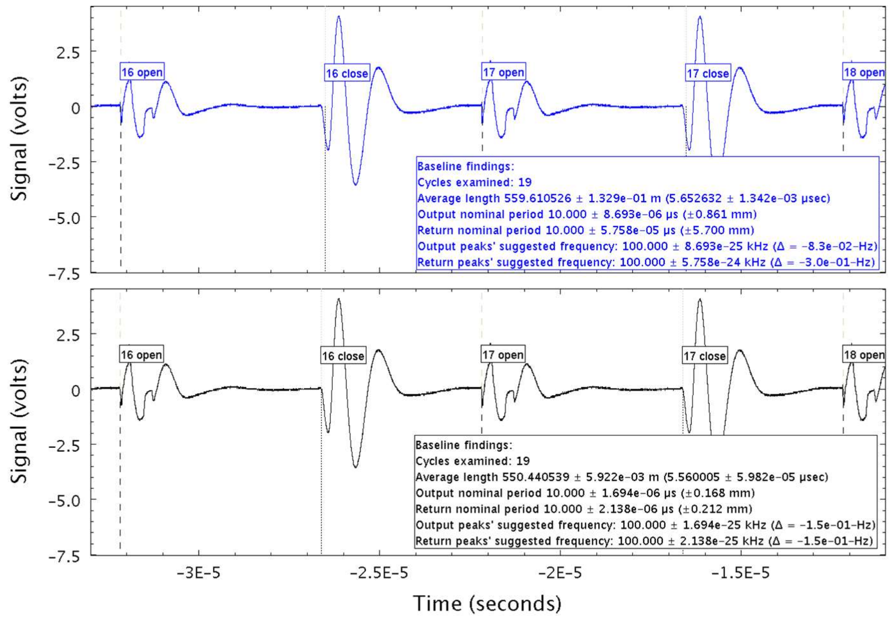

Figure 12. Baseline analysis of DAG data; pseudo-wavelets results are in black, and threshold results are in blue.

During experiment emplacement, baseline data were collected periodically – nearly every morning – to verify that CORRTEX cables were unharmed by the emplacement process. Using nominal pulse forms defined from a single instance of baseline data, pseudo-wavelets analysis of cable length in each data set allowed measurements of the apparent change in the cable length as environmental conditions changed. It is believed that most of the variation resulted due to changes in the ambient temperature at the DAG site. Similar analyses had been performed for previous experiments using other analysis algorithms; however, scatter was far higher without the ability to normalize results using a consistent nominal for the pulse shape.

Data from DAG-2 day-to-day cable measurements are included as Figure 13. It can be noted that all cable round-trip delays trend higher or lower together, indicating that the variation has a common cause for all cables.

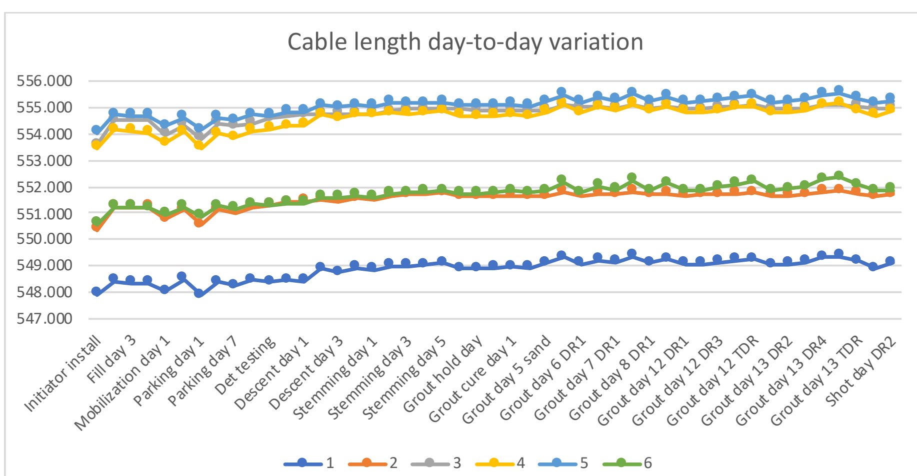

Figure 13. Example plot of DAG-2 CORRTEX measurements showing day-to-day variation in apparent cable length; vertical axis units are meters of cable delay = 0.5 · Δtime · transmission speed.

4.2.3 DAG-2 Dynamic Data

Data from the DAG-2 dynamic experiment are shown in Figure 14 for pseudo-wavelets and Figure 15 for thresholds analysis, along with fits to the linear region after the detonation shock was fully developed. Note the difference in smoothness and the length variation that results from use of the thresholds-based analysis.

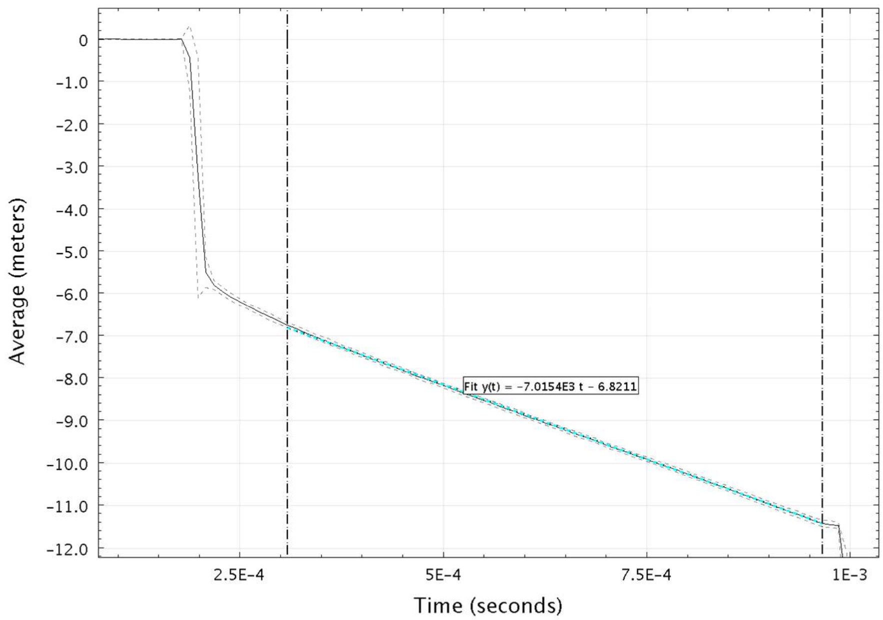

Figure 14. Average of DAG-2 outer-wall CORRTEX channels analyzed using a pseudo-wavelets algorithm; dashed lines indicate variation among the channels included. R-squared for the linear fit is 0.9998, and uncertainty in the detonation speed is 12.

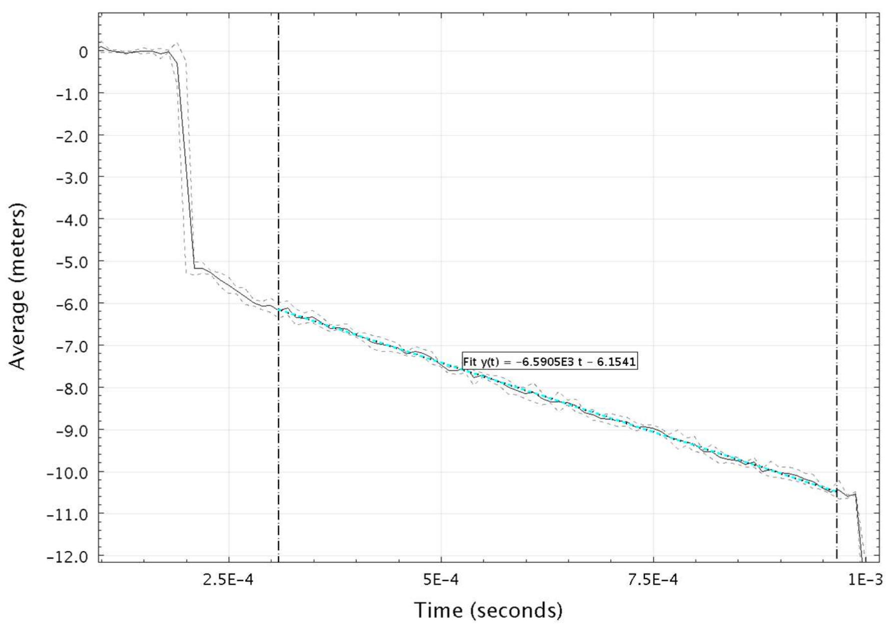

Figure 15. Average of DAG-2 outer-wall CORRTEX channels analyzed using a thresholds-based algorithm; dashed lines indicate variation among the channels included. R-squared for the linear fit is 0.998, and uncertainty in the detonation speed is 38.

4.2.4 DAG-1 Dynamic Data

Dynamic data in DAG-1 included only 7-8 points of cable length measurement prior to consumption of all the explosive in the experiment. The pseudo-wavelets analysis results are included here for comparison with the IST data in the next section. Data compare favorably with predictions of the detonation front made with a simple analytical model. Comparisons with the predictive modeling are shown as Figure 16.

DAG-1 Corrtex results showed cable consumption rates faster than standard nitromethane detonation rates. However, this is because the detonation was initially overdriven by the initiation assembly, and there was insufficient explosive charge to achieve a steady-state detonation shock.

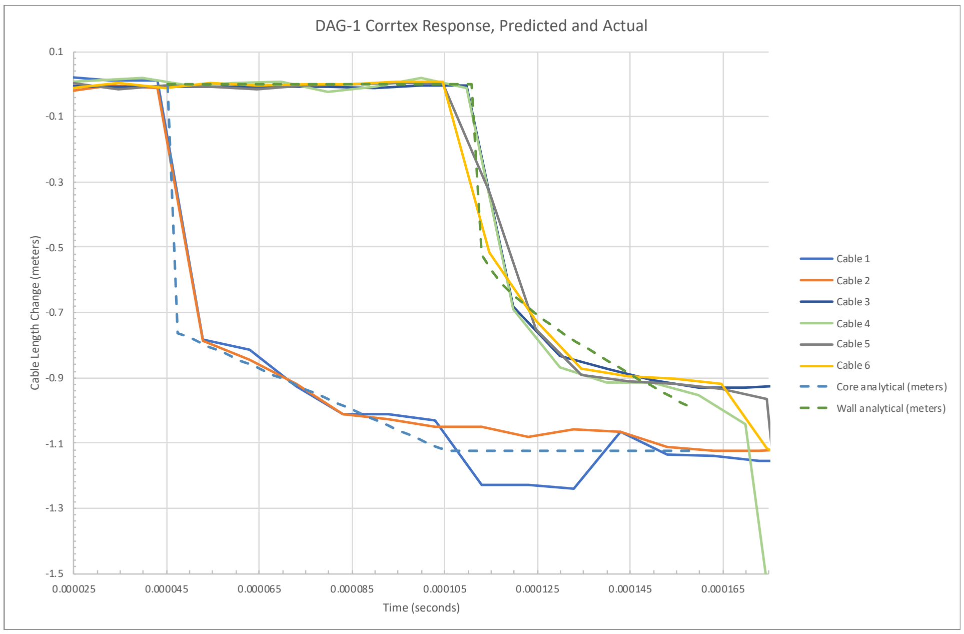

Figure 16. DAG-1 data results (solid lines) compared with analytical predictions (dashed lines)

4.3 IST Canister Data

The IST experiment design was similar to the DAG design, and the IST canister is shown in Figure 17. The primary difference that affected comparisons between the IST and DAG-1 results was a change in the initial jump length, which was longer by a foot (0.3 meters) in the wall channels and very short in the axial channels.

The weak signal strength, as shown above in Figure 4, posed a challenge during data analysis. The data proved intractable to a thresholds-based analysis due to the curvature in the signal baseline in the regions surrounding the return pulses. However, pulse shapes were consistent enough that a pseudo-wavelets analysis yielded reasonable results. Figure 18 shows some sample analysis results from IST data, with the return pulse integral shown. As can be seen in the figure, pseudo-wavelets results lead to robust pulse locations, even when there's significant curvature in the baseline voltage level.

Figure 17. IST canister; similar to the DAG experiments, wall CORRTEX cables are installed within channels formed by welding angle bracket where shown.

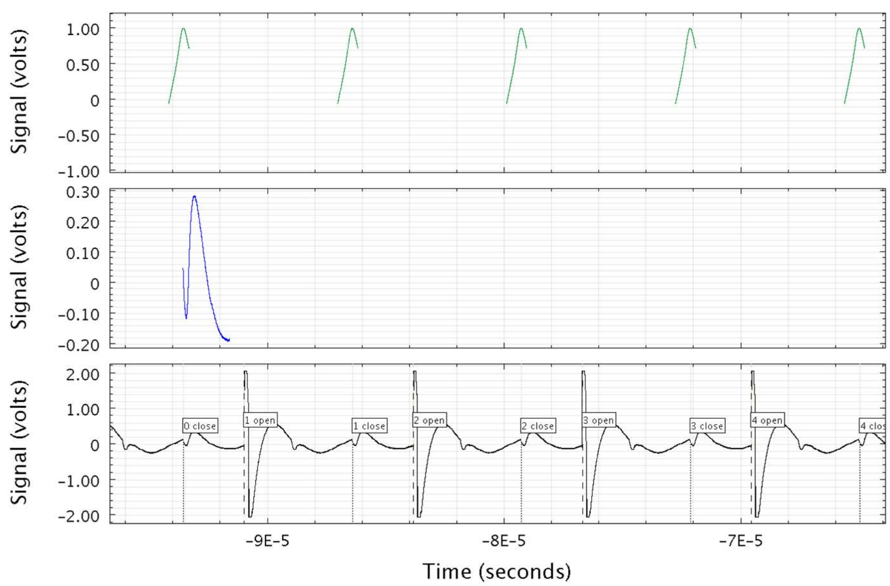

Figure 18. Analysis of IST return pulses; data are shown below, in black, the nominal return pulse in blue, and the returns integral in green at the top. As in Figure 8, disallowed portions in the integral are omitted.

As with DAG-1, data were not as smooth as in DAG-2 due mostly to the low number of data points that could be collected before the explosive charge was fully expended. A comparison of wall channel CORRTEX results between IST and DAG-1 is shown in Figure 19, and a comparison of axis channel results in Figure 20. Uncertainty in pulse locations is shown as dashed lines in both figures. As can be seen in the figures, uncertainty and variation were higher in IST results, most likely due to two factors: 1) the oversaturation of the digitizer channel by the output pulses, and 2) the small size and shape of the return pulses. These factors were difficult to minimize during fielding due to the CORRTEX system configuration – an increase in return pulse signal also resulted in an output pulse signal. However, as can be seen in the figures, detonation wave symmetry and the steady pace of cable consumption were clear in data from both experiments despite the challenges.

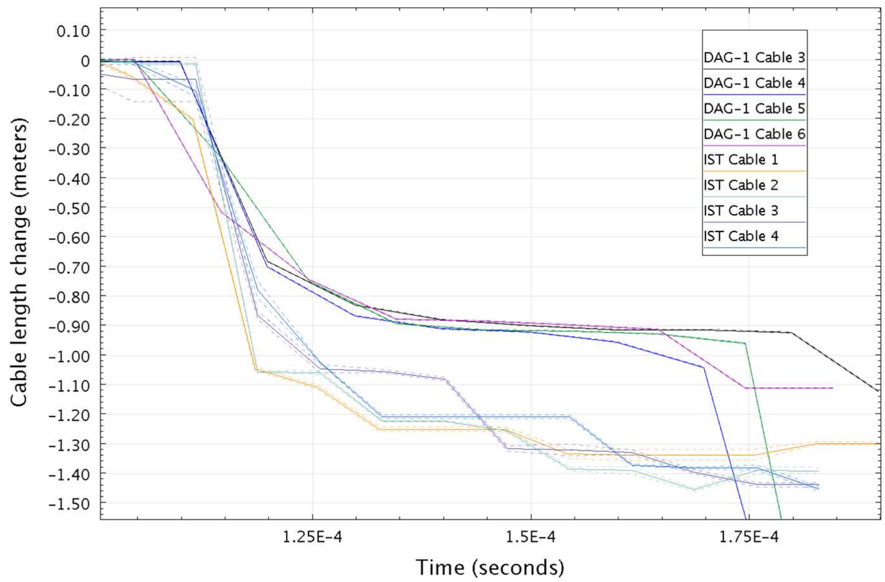

Figure 19. Wall channel CORRTEX results from DAG-1 (in black) and IST (in blue); dashed lines indicate uncertainty in the cable length at each point.

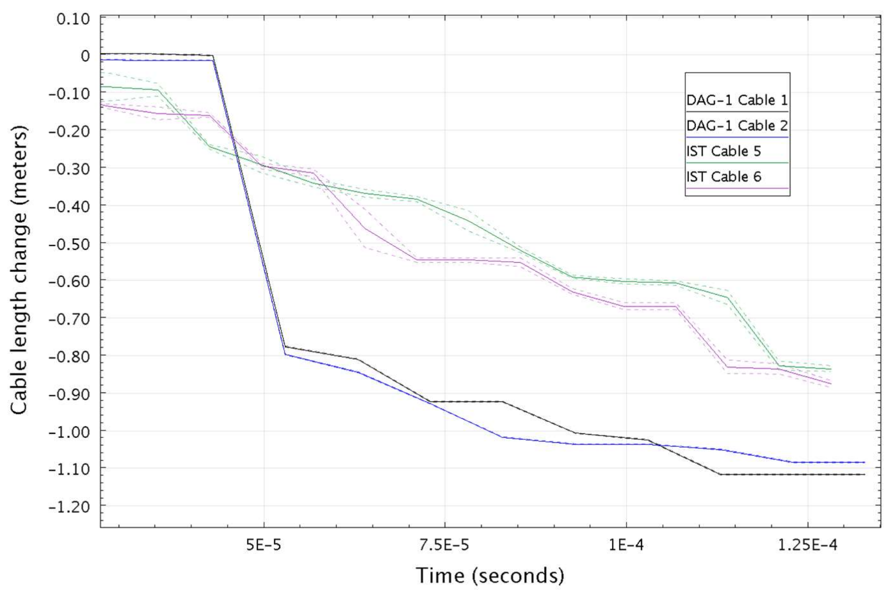

Figure 20. Axis channel CORRTEX results from DAG-1 (in black) and IST (in blue); dashed lines indicate uncertainty in the cable length at each point.

5 Conclusions

An introduction to CORRTEX system choices and analysis concerns was given in section 2, and approaches to data analysis in section 3. Some results from the thresholds-based and pseudo-wavelets-based analysis approaches were given. While using a thresholds-based analysis will produce reasonable results from CORRTEX data from an ideal system, use of a pseudo-wavelets approach will give superior levels of uncertainty and channel-to-channel variability. The pseudo-wavelets analysis algorithm is also significantly more robust to flaws in the CORRTEX system, and was found to be a capable tool to reduce data collected during less-than-ideal experimental circumstances.